Solidification of Magnetic Liquid Marbles

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Liquid marbles, which are formed usually by rolling a liquid droplet over a hydrophobic powder, are attracted much more attention due to increasing demands to transport or manipulation of small volumes of fluids, micropumps, sensors and miniature reactors. Stimuli-responsive liquid marbles can be manipulated with the changing pH, temperature or magnetic field and allows to use in various applications. Especially, magnetic liquid marbles provide transportation of core liquid and serve as miniature reactors by means of opening and closing the top of the marble with a permanent magnet.

We have studied to form magnetic liquid marbles with hydrophobic iron oxide nanoparticles. Then, obtained liquid marble was used as a model miniature reactor. First of all, approximately 6 nm sized water soluble magnetite nanoparticles (MNPs) were synthesized via a well known co-precipitation method [1]. To modify the surface of iron oxide nanoparticles, a perfluorinated ligand was added to the MNPs solution and interacted. Thus, hydrophobic iron oxide nanoparticles were obtained. To form liquid marbles, particles were dried, ground and various volumes of water droplets were rolled over this hydrophobic powder. Magnetic actuation can be performed when a permanent magnet is approached to the liquid marble and it was determined that the velocity of marbles under a magnetic field were considerably high. When a liquid marble was hold above a magnet, top of the marble was opened, and when the magnet was removed, top of the marble was closed again. This process is a reversible process and can be repeated for more than 10 times. As a reactor, opening and closing process allows adding various reactants after the formation and transportation of marble. A linear relation was determined between the height and diameter values, that means formation of approximately spherical shaped small magnetic liquid marbles and gravitationally flattened puddles were obtained when the large volume of water droplets was used to form liquid marbles.

As a model reaction, gelation of a gelatin solution was performed inside of the liquid marble. To achieve this, a gelatin solution was prepared at 50°C and this solution was used to form the liquid marble. When this solution was cooled to room temperature, reaction was completed in 3 minutes and gelation was occurred. Also, gelation reaction provided a mechanical robustness for marbles. Therefore, solidification of a liquid marble was obtained and it was possible to pick it up and press or stick a needle through it without rupture of the marble.

[1] W. Wu, Z. Wu, T. Yu, C. Jiang and W. Kim, *Sci. Technol. Adv. Mater.*, 2015, 16, 023501. (43pp).